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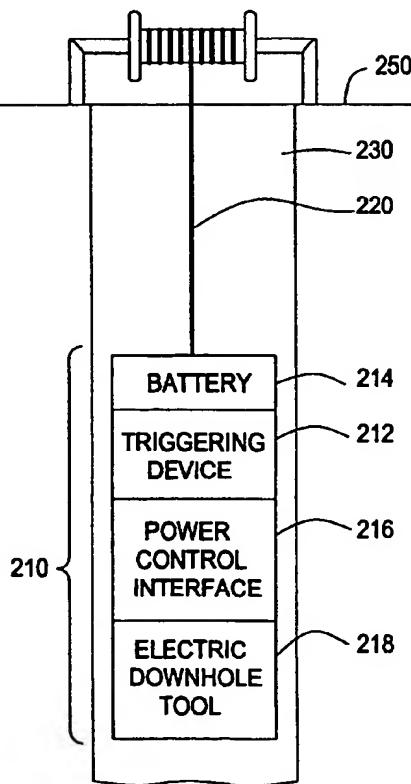
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(54) Title: SLICKLINE POWER CONTROL INTERFACE

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(57) Abstract: Embodiments of the present invention generally provide an apparatus, method, and system for operating an electric downhole tool on a non-conductive support line (slickline) by converting a battery voltage to an output voltage suitable for operating the tool. In response to receiving a trigger signal, the output voltage signal is applied to the tool. The tool is controlled by varying the output voltage signal according to a power control sequence. Accordingly, electric tools typically requiring surface intervention by an operator via an electric cable (wireline) may be operated on slickline.



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SLICKLINE POWER CONTROL INTERFACE

BACKGROUND OF THE INVENTION

Field of the Invention

5 Embodiments of the present invention generally relate to downhole logging and production operations and particularly to deployment of downhole tools on non-electric cable.

Description of the Related Art

Costs associated with downhole drilling and completion operations have been 10 significantly reduced over the years by the development of tools that can be deployed down a well bore to perform operations without pulling production tubing. Downhole tools are typically attached to a support cable and subsequently lowered down the well bore to perform the desired operation. Some support cables, commonly referred to as wirelines, have electrically conductive wires through which 15 voltage may be supplied to power and control the tool.

Figure 1 illustrates an exemplary electric downhole tool 110 attached to a wireline 120, lowered down a well bore 130. The wireline 120 comprises one or more conductive wires 122 surrounded by an insulative jacket 124. The conductive wires 122 supply a voltage signal to the tool 110 from a voltage source 140 at the surface 20 150. Typically, an operator at the surface 150 controls the tool 110 by varying the voltage signal supplied to the tool 110. For example, the operator may apply and remove the voltage signal to cycle power on and off, adjust a level of the voltage signal, or reverse a polarity of the voltage. The tool 110 is designed to respond to 25 these voltage changes in a predetermined manner. As an example, an inflatable setting tool may toggle between a high volume-low pressure pump and a low volume high-pressure pump when power is cycled.

A less expensive, non-electric support cable is commonly referred to as slickline. Because slickline has no conductive lines to supply power to the attached tool, the types of the tools deployed on slickline are typically non-electric tools, such as 30 placement and retrieval tools, mandrels, etc. Recently, battery powered tools have recently been developed for slickline operation. Operation of the battery powered

tools may be initiated by lowering a slip ring device down the slickline that comes in contact with a switching device on a top surface of the tools. Alternatively, operation of the tools may be initiated by a triggering device that generates a trigger signal, for example, based upon bore hole pressure (BHP), bore hole temperature (BHT), and 5 tool movement. Regardless of the method of initiation, the absence of electrically conductive wires prevents conventional surface intervention used to control wireline tools, which typically limits tools deployed on slickline to simple tools requiring little or no control, such as logging tools.

Accordingly, what is needed is an improved method and apparatus for operating 10 electric downhole tools deployed on slickline.

SUMMARY OF THE INVENTION

Embodiments of the present invention generally provide a method, apparatus and system for operating an electric downhole tool on a non-conductive support line (slickline). The method comprises generating an output voltage signal from a 15 battery voltage signal, applying the output voltage signal to the tool in response to receiving a trigger signal, and varying the output voltage signal applied to the tool to autonomously control the tool.

The apparatus comprises an output voltage circuit to generate an output voltage signal from a battery voltage signal and apply the output voltage signal to the tool in 20 response to one or more control signals, and a microprocessor configured to autonomously control the tool by generating the one or more control signals according to a power control sequence stored in a memory.

The system comprises a non-electric cable, an electric downhole tool attached to the non-electric cable, and a power control interface comprising an output voltage circuit 25 to generate an output voltage signal from a battery voltage and a microprocessor configured to autonomously control the tool by applying the output voltage signal to the tool and varying the output voltage signal according to a power control sequence stored in a memory, wherein the power control sequence is initiated by a trigger signal.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features of the present invention, and other features contemplated and claimed herein, are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

Figure 1 illustrates an exemplary wireline tool according to the prior art.

Figure 2 illustrates an exemplary slickline tool string according to one embodiment of the present invention.

Figure 3 illustrates a block diagram of a power control interface according to an embodiment of the present invention.

Figure 4 illustrates a schematic view of a power control interface according to an embodiment of the present invention.

Figure 5 is a flow diagram illustrating exemplary operations of a method according to an embodiment of the present invention.

Figure 6 illustrates an exemplary tool string comprising an inflatable tool according to an embodiment of the present invention.

Figure 7 is a flow diagram illustrating exemplary operations of a method for operating an inflatable tool according to an embodiment of the present invention.

Figure 8 is an exemplary voltage-current diagram of an inflatable tool.

Figures 9A and 9B illustrate a side view and a top view, respectively, of an exemplary tool string for perforating a pipe according to an embodiment of the present invention.

Figure 10 is a flow diagram illustrating exemplary operations of a method for
5 operating a perforating tool according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Embodiments of the present invention generally provide an apparatus, method, and system for operating an electric downhole tool on a non-conductive support line (slickline). An advantage to this approach is that electric tools typically requiring
10 voltage supplied through a wireline may be operated on the less expensive slickline, thereby reducing operating costs. Further, by enabling slickline operation of existing tools designed to operate on wireline, costly design cycles to develop new electric tools for operation on slickline may be avoided.

Figure 2 illustrates an exemplary downhole tool string 210 attached to a non-electric
15 cable (slickline) 220, which is lowered down a well bore 230. The tool string 210 comprises a triggering device 212, a battery 214, a power control interface 216 and an electric downhole tool 218. The power control interface 216 provides autonomous control of the tool 218, which may be any suitable downhole tool, such as those typically operated on electric cables (wireline). For example, the tool 218
20 may perform bail ing operations, set a mechanical plug or packer, or set an inflatable plug or packer. Power control operations traditionally performed via wireline by an operator on a surface 250 are performed by the power control interface 216. As used herein, the term autonomous means without intervention from the surface. In other words, once the tool is activated (*i.e.*, triggered, the tool operates without
25 surface intervention).

The triggering device 212 generates a trigger signal upon the occurrence of predetermined triggering conditions. For example, the triggering device 212 may monitor parameters such as bore hole temperature (BHT), bore hole pressure (BHP), and movement of the tool string 210. The triggering device 212 may

generate a trigger signal upon determining the tool string 210 has stopped moving (i.e. has reached a desired depth) and that the BHT and BHP are within the operating limits of the tool 218. Alternatively, as previously described, a trigger signal may be generated by lowering a slip ring device (not shown) down the 5 slickline 220 to contact a switch (not shown) on a top surface of the triggering device 212.

The trigger signal may be any suitable type signal, and for some embodiments, the triggering device 212 may supply a voltage signal from the battery 214 to the power control interface 216 as a trigger signal. The battery 214 may be any suitable 10 battery capable of providing sufficient power to operate the tool 218. A physical size of the battery 214 depends on the operating power of the tool. For example, a battery capable of supplying 120 volts at 1.5 amps to a tool for .5 hours may be over six feet long if a diameter of the well bore is 2.5 inches.

In response to receiving the trigger signal, the power control interface 216 converts 15 a voltage signal from the battery 214 into an output voltage signal suitable for operating the tool 218. The power control interface 216 applies the output voltage signal to the tool 218. The power control interface 216 autonomously controls the tool 218 by varying the output voltage signal applied to the tool 218 according to a predetermined power control sequence. Hence, the combination of the battery 214 20 and the power control interface 216 acts as an intelligent power supply.

For some embodiments, the tool assembly may be lowered down the wellbore on a lowering member other than a slickline, such as a coiled tubing. The methods and apparatus described herein for operating an electric tool on slickline may also be applied to operating an electric tool deployed on coiled tubing. In other words, there 25 is typically no power supplied to a tool assembly deployed on a coiled tubing.

POWER CONTROL INTERFACE

Figure 3 illustrates a block diagram of an embodiment of the power control interface 216. As illustrated, the power control interface 216 comprises a regulator circuit

310, a power control logic circuit 320, an output voltage converter 330, a current monitor 350, a voltage monitor 360, and sensors 370.

The regulator circuit 310 regulates the trigger signal (which may be the battery voltage signal) to a suitable voltage level to operate the power control logic circuit 320. The output voltage converter 330 converts the battery voltage signal to an output voltage signal V_{out} as a function of control signals 342 generated by the power control logic circuit 320. The control signals 342 determine a level of V_{out} and whether V_{out} is applied to the tool. Exemplary output voltages include, but are not limited to 24V, 120V, and 180V, and may be AC or DC. The output voltage converter 330 may comprise any suitable circuitry such as digital to analog converters (DACs), mechanical relays, solid state relays, and/or field effect transistors (FETs). Further, the output voltage converter 330 may generate different output voltages V_{out} to power and control different tools autonomously.

The current monitor 350 and voltage monitor 360 monitor a current draw of the tool and a voltage applied to the tool, respectively, and provide analog inputs 344 to the power control logic circuit 320. Sensors 370 may comprise any combination of suitable sensors, such as a pressure sensor 372, a temperature sensor 374 and an accelerometer 376. For some embodiments, the power control logic circuit 320 may determine a triggering event has occurred based on analog inputs 344 provided by the sensors 370, eliminating a need for the external triggering device 212.

For some embodiments, the power control logic 320 may determine if one or more parameters in the wellbore are within a predetermined range prior to operating the tool 218. For example, the tool 218 may be an inflation tool and the power control logic 320 may confirm that downhole temperature is compatible with materials of an inflatable element prior to operating the tool to set the inflatable element. Further, for some embodiments, the power control logic 320 may also include circuitry for wireless communication of data from the sensors 370 to a surface. Monitoring downhole parameters prior to operating a tool and communicating sensor data to a surface is described in an application, filed herewith on August 5, 2002, entitled

"Inflation Tool with Real-Time Temperature and Pressure Probes" (Attorney Docket Number WEAT/0241), hereby incorporated by reference.

The power control logic circuit 320 may be any suitable circuitry to autonomously control the tool by varying the output voltage V_{out} applied to the tool 218 according

5 to a predetermined power control sequence. For example, as illustrated in Figure 4, the power control logic circuit 320 may comprise a microprocessor 322 in communication with a memory 324. Figure 4 is an exemplary schematic view of the power control interface 216.

Figure 5 is a flow diagram illustrating exemplary operations of a method 500 according to an embodiment of the present invention. Figure 5 may be described with reference to the exemplary embodiment of Figure 4. However, it will be appreciated that the exemplary operations of Figure 5 may be performed by embodiments other than that illustrated in Figure 4. Similarly, the exemplary embodiment of Figure 4 is capable of performing operations other than those illustrated in Figure 5. It should also be noted that the listed components may be extended temperature components, suitable for downhole use (downhole temperatures may reach or exceed 300° F).

The method 500 begins at step 510, by receiving a trigger signal from a triggering device. The trigger signal is regulated by the regulator circuit 310 to a supply voltage V_{cc} suitable to power the power control logic circuit 320. The regulator circuit 310 may comprise a single regulator chip 312, or any other suitable circuitry. A reset circuit 314 holds the power control logic circuit 320 in a reset condition for a short period of time to ensure the trigger signal is valid and that the supply voltage V_{cc} is stable.

25 For some embodiments, the power control logic circuit 320 may be powered from the trigger signal. Alternatively, the power control logic circuit 320 may be powered from an internal battery (not shown) or the external battery 214. A current draw of the power control logic circuit 320 may be insignificant when compared to a current draw of an attached tool 218. For some embodiments, the triggering device 212 supplies a battery voltage signal from the battery 214 as a trigger signal.

The power control logic circuit 320 comprises a microprocessor 322 and a memory 324. The microprocessor 322 may be any suitable type microprocessor configured to perform the power control sequence 326. The microprocessor may also be an extended temperature microprocessor suitable for downhole operations. Examples 5 of extended temperature microprocessors include the 30100600 and 30100700 model microprocessors, available from Elcon Technology of Phoenix, AZ, which are rated for operation up to 175°C (347°F).

The memory 324 may be internal or external to the microprocessor and may be any suitable type memory. For example, the memory 324 may be a battery-backed 10 volatile memory or a non-volatile memory, such as a one-time programmable memory (OT-PROM) or a flash memory. Further, the memory may be any combination of suitable external or internal memories.

The memory 324 may store a power control sequence 326 and a data log 328. The data log 328 may store data read from the current monitor 350, voltage monitor 360, 15 and sensors 370. For example, subsequent to operating the tool, the power control interface 216 may be retrieved from the well bore and the data log 328 may be uploaded from the memory 324 via the program/data interface lines 346 using any suitable communications protocol, such as a serial communications protocol. The data log 328 may provide an operator with valuable information regarding operating 20 conditions.

The power control sequence 326 may be stored in any data format suitable for execution by the microprocessor 322. For example, the power control sequence 326 may be stored as executable program instructions. Alternatively, the power control sequence may be stored as parameters in a data file that specify voltage 25 levels and cycle times or other parameters, such as temperature and/or pressure thresholds. The power control interface 216 may be configured to perform different power control sequences, thus allowing autonomously control of different tools. For example, different power control sequences may define output voltages of differing levels so a power control interface 216 may control tools with different operating 30 voltages.

For some embodiments, the power control sequence 326 may be generated on a computer using any suitable programming tool or editor. For example, the power control sequence may be generated by compiling a ladder logic program created using a ladder logic editor. The ladder logic program may define various voltage

5 levels, switching times and switching events, for example, based on inputs from the current monitor 350, voltage monitor 360, and sensors 370.

Alternatively, a power control sequence may be selected from a number of predefined power control sequences, for example, correspond to operating sequences for different tools. Accordingly, for some embodiments, a power control

10 sequence may be chosen by selecting the corresponding tool. The power control sequence 326 may be downloaded to the memory 324 via the program/data interface lines 346 using any suitable communications protocol, such as a serial communications protocol.

Further, a set of predefined power control sequences may be stored in the memory

15 324. For some embodiments, the power control interface 216 may be configured by selecting one of the predefined power control sequences, for example, by downloading a selection parameter or by setting a selection switch on a PCB of the power control interface 216. The microprocessor 322 may read the downloaded selection parameter or the selection switch to determine which predetermined power
20 control sequence to execute.

For step 520, an output voltage signal is generated from a battery voltage signal.

For step 530, the output voltage signal is applied to the tool in response to receiving a trigger signal. The output voltage signal V_{out} may be substantially equal to the battery voltage signal, or the output voltage converter 330 may transform (i.e. step up or step down) the battery voltage signal to generate a different output voltage

25 signal. A voltage level of V_{out} is determined by the tool 218, and a particular time in the power control sequence 326. For some embodiments, V_{out} may be generated from the battery voltage signal prior to receiving the trigger signal. However, V_{out} is not applied to the tool 218 prior to receiving the trigger signal.

For step 540, the output voltage signal applied to the tool is varied to autonomously control the tool. The output voltage signal V_{OUT} is varied according to the power control sequence 326 performed by the microprocessor. The output voltage converter 330 may comprise any suitable circuitry to vary V_{OUT} in response to control signals 342 generated by the microprocessor 322, as required by the power control sequence.

For example, the output voltage converter 330 may comprise a combination of relays 332 and 334 to apply V_{OUT} to the tool 218. The relay 332 serves as a switch to apply V_{OUT} to, or remove V_{OUT} from, the tool 218. The relay 334 comprises a double pole relay suitable for reversing a polarity of V_{OUT} , by reversing a polarity of traces connected to different sets of inputs. In a first state, the relay 334 applies a positive V_{OUT} to the tool 218, and in a second state the relay 334 applies a negative V_{OUT} to the tool 218.

For other embodiments, the output voltage converter 330 may comprise other circuitry, such as digital to analog converters (DACs) to generate voltage steps of various levels in response to the control signals 342. As illustrated, an output filter circuit 336 may be disposed between the output voltage converter 330 and the tool 218. The output filter circuit 336 may comprise any suitable circuitry to filter V_{OUT} applied to the tool 218, and may also function as a surge arrestor to prevent a large in-rush of current from the tool upon initial application and/or disconnections of V_{OUT} to the tool 218. Further, the microprocessor 322 may be configured to perform a soft start of the tool 218 by slowly raising V_{OUT} to a final value (for example, by pulsing the filter circuit 336) in an effort to minimize a stress and extend a life of the tool 218.

For some embodiments, the microprocessor 322 may vary V_{OUT} as a function of one or more parameters monitored by sensors 370. For example, the microprocessor may discontinue operation if an operating temperature of the tool is exceeded. As another example, the microprocessor 322 may monitor a current draw of the tool as indicated by an analog input 345 generated by the current monitor 350. The microprocessor 322 may disconnect V_{OUT} in response to determining the current

draw to the tool has reached a predefined threshold limit, which may indicate a known event, such as a problem with the tool 218 or completion of a tool operation.

Further, for some embodiments, the microprocessor 322 may execute a power control sequence to autonomously control a plurality of tools. For example, the 5 output voltage converter may include circuitry to generate more than one voltage, suitable for simultaneously operating more than one tool. The microprocessor 322 may operate a different power control sequence for tool, varying an output voltage supplied to each tool.

AUTONOMOUS INFLATABLE TOOL OPERATION

10 An example of a tool that may be autonomously operated by monitoring current draw to the tool is an inflatable tool. Figure 6 illustrates an exemplary tool string 610 comprising a triggering device 612, a battery 614, a power control interface 616 and an inflatable tool 618. As illustrated, the inflatable tool 618 may comprise a high volume-low pressure pump 622 and a low volume-high pressure pump 624 for 15 inflating an inflatable member 626.

Figure 7 is a flow diagram illustrating exemplary operations of a method 700 for operating an inflatable tool according to an embodiment of the present invention. The exemplary operations of Figure 7 may be illustrated with reference to Figure 6 and Figure 8, which illustrates an exemplary graph of current and voltage supplied to 20 an inflatable tool as a function of time. The voltages, currents and time are for illustrative purposes only, and may vary according to a particular inflatable tool.

Steps 710 through 730 mirror the operations of steps 510 through 530 of Figure 5. The method 700 begins at step 710, by receiving a trigger signal from a triggering device. For step 720, an output voltage signal is generated from a battery voltage 25 signal. For step 730, the output voltage signal is applied to the inflatable tool in response to receiving the trigger signal. In response to the applied voltage signal, the inflatable tool may begin inflating the inflatable member 626 with the high volume-low pressure pump 622.

For step 740, a current draw of the inflatable tool is monitored. For step 750, the output voltage supplied to the inflatable tool is removed in response to determining the current draw of the inflatable tool is greater than a first threshold value. For example, the current draw of the inflatable tool 618 may be proportional to a

5 pressure of an inflatable member 626. Referring to Figure 8, a sharp rise 810 in the current draw of the inflatable tool, may indicate the high volume-low pressure pump 622 has inflated the inflatable member 626 to a predetermined pressure. The output voltage signal disconnected from the inflatable tool corresponds to the zero voltage in Figure 8 for the cycle time T_{OFF} .

10 For step 770, the output voltage signal is again applied to the inflatable tool 618. In response to the output voltage signal applied again, the inflatable tool may begin inflating the inflatable member 626, this time with the low volume-high pressure pump 624, which may be able to inflate the inflatable member 626 to a higher pressure than the high volume-low pressure pump 622. For some inflatable tools, a

15 second pump (or pumping operation) may be operated by applying a voltage signal of opposite polarity to the inflatable tool. Therefore, for optional step 760, a polarity of the output voltage signal is reversed prior to again applying the output voltage signal to the inflatable tool.

For step 780, the output voltage signal is removed from the inflatable tool 618 in

20 response to determining the current draw of the inflatable tool has fallen below a second threshold value. For example, the inflatable tool 618 may be designed to automatically release from the inflatable member 626 when the inflatable member 626 is inflated to a predetermined pressure. This automatic release may be indicated by a sharp decrease 820 in the current draw of the inflatable tool 618.

25 **AUTONOMOUS PERFORATING TOOL OPERATION**

Another example of a tool that may be autonomously operated by a power control interface is a perforating tool. Figures 9A and 9B illustrate a side view and a top view, respectively, of an exemplary tool string 910 attached to a slickline 920. The tool string 910 comprises a trigger device 912, a battery 914, a power control

30 interface 916 and a perforating tool 918 for perforating a pipe 932. The perforating

tool 918 may be anchored to a fixed location in the pipe 932 prior to the operations described below. For example, the perforating tool 918 may be anchored by an inflatable packing device (not shown), according to the previously described method. One challenge in operating the perforating tool 918 is to perforate the pipe 932 without causing damage to an adjacent pipe 942.

Accordingly, the perforating tool 918 may comprise a ferrous sensor 924 to detect a location of the adjacent pipe 942. As illustrated in Figure 9B, the ferrous sensor 924 may be located to generate a signal when a perforating device 922 is pointing in an opposite direction of the adjacent pipe 942. The tool 924 is commonly referred to as an electromagnetic orienting (EMO) tool. The power control interface may generate a signal to rotate the perforating tool 918 while monitoring the signal generated by the ferrous signal to determine a direction of the perforating device 922 with respect to the adjacent pipe 942. The power control signal 916 may then generate a signal to fire the perforating device 922 in response to determining the perforating device 922 is pointing away from the adjacent pipe 942.

Figure 10 is a flow diagram illustrating exemplary operations of a method 1000 for operating a perforating tool according to an embodiment of the present invention. At step 1010, the power control interface 916 receives a trigger signal from the triggering device 912. At step 1020, the power control interface 916 generates a signal to rotate the perforating tool 918 while monitoring the signal generated by the ferrous sensor 924. At step 1030, the power control interface 916 may then generate a firing signal to fire the perforating device 922 in response to determining the perforating device 922 is pointing away from the adjacent pipe 942.

Because of the possible damage that may be caused to the adjacent pipe, additional steps may be taken for redundancy. For example, the power control interface 916 may rotate the perforating device 922 at least one additional rotation while monitoring the signal generated by the ferrous sensor 924. The power control interface 916 may compare a location indicated by the signal generated on the additional rotation to a location indicated by the prior signal to ensure both signals indicate a consistent location. If both signals indicate a consistent location, the

power control interface 916 may generate the firing signal to fire the perforating device 922. However, if the signals indicate inconsistent results, additional rotations may be monitored or the operations may be terminated to avoid possibly damaging the adjacent pipe 942.

- 5 For some embodiments, the ferrous sensor 924 and perforating device 922 may rotate independently of each other. Accordingly, the method described above may be modified such that the power control interface 916 may rotate the ferrous sensor 924 to determine a location of the adjacent pipe 942 and subsequently rotate the perforating device 922. Further, the method described above may also be modified
- 10 to fire a perforating device away from more than one adjacent pipe.

CONCLUSION

Embodiments of the present invention provide a method, system and apparatus for autonomous control of downhole tools on inexpensive slickline, which may reduce operating costs. A power control interface performs power control operations

- 15 traditionally performed via wireline by an operator on the surface. Accordingly, operating costs may be further reduced by limiting a number of skilled operators required to operate the tool.

While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the

- 20 basic scope thereof, and the scope thereof is determined by the claims that follow.

Claims:

1. A method for operating an electric downhole tool attached to a non-electric cable comprising:
 - generating an output voltage signal from a battery voltage signal;
 - 5 applying the output voltage signal to the tool in response to receiving a trigger signal; and
 - varying the output voltage signal applied to the tool to autonomously control the tool.
- 10 2. The method as claimed in claim 1, wherein the output voltage signal is less than the battery voltage signal.
3. The method as claimed in claim 1, wherein the output voltage signal is greater than the battery voltage signal.
- 15 4. The method as claimed in claim 1, wherein varying the output voltage signal applied to the tool comprises removing the output voltage signal from the tool and again applying the output voltage signal to the tool.
- 20 5. The method as claimed in claim 1, wherein varying the output voltage signal applied to the tool comprises reversing a polarity of the output voltage signal.
6. The method as claimed in claim 1, further comprising monitoring a current draw of the tool, and wherein varying the output voltage signal applied to the tool comprises varying the output voltage signal supplied to the tool as a function of the current draw.
- 25 7. The method as claimed in any preceding claims, wherein the tool is an inflation tool.
- 30 8. The method as claimed in any preceding claim, further comprising monitoring one or more sensors and logging data from the one or more sensors.

9. A method for controlling an electric downhole tool attached to a lowering member comprising:

5 generating an output signal from a battery signal;
receiving a trigger signal by a microprocessor; and
in response to receiving the trigger signal, applying the output signal to the tool according to a power control sequence executed by the microprocessor.

10. The method as claimed in claim 9, wherein operations of the power control 10 sequence comprise applying the output signal to the tool, removing the output signal from the tool, and again applying the output signal to the tool.

11. The method as claimed in claim 10, further comprising reversing a polarity of the output signal prior to again supplying the output signal to the tool.

15 12. The method as claimed in claim 9, wherein the tool is an inflatable tool and the power control sequence comprises:

monitoring a current draw of the tool;
applying the output signal to the tool;
20 removing the output signal from the tool in response to determining the current draw of the tool has exceeded a first threshold level;
again applying the output signal to the tool; and
removing the output signal from the tool in response to determining the current draw of the tool has fallen below a second threshold level.

25 13. The method as claimed in claim 12, wherein the second threshold level is indicative of the inflatable tool automatically releasing from an inflatable member.

30 14. The method as claimed in claim 12, wherein applying the output signal to the tool operates a first pump and wherein removing the output signal from the tool and again applying the output signal to the tool operates a second pump.

15. The method as claimed in claim 14, wherein the first pump is a high volume-low pressure pump and the second pump is a low volume-high pressure pump.

16. The method as claimed in any preceding claim, wherein the lowering member
5 is a coiled tubing.

17. A method for operating an electromagnetic orienting (EMO) perforating tool attached to a non-electric cable in a first pipe adjacent to a second pipe, the method comprising:

10 receiving a trigger signal to initiate operation of the perforating tool;
rotating the perforating tool while monitoring a sensor for a signal indicative of a location of the second pipe; and
firing the perforating tool in response to detecting the signal indicative of a location of the second pipe.

15 18. The method as claimed in claim 17, wherein rotating the perforating tool while monitoring a sensor for a signal indicative of a location of the second pipe comprises:

20 detecting a first signal indicative of a location of the second pipe;
rotating the perforating tool at least one additional rotation subsequent to detecting the first signal;
detecting a second signal indicative of a location of the second pipe; and
determining the first signal and the second signal indicate consistent locations for the second pipe prior to firing the perforating tool.

25 19. The method as claimed in claim 17, wherein rotating the perforating tool comprises independently rotating a first portion of the perforating tool comprising a ferrous sensor and a second portion of the perforating tool comprising a perforating device.

30 20. An apparatus for operating an electric downhole tool attached to a non-electric cable comprising:

an output voltage circuit to generate an output voltage signal from a battery voltage signal and apply the output voltage signal to the tool in response to one or more control signals; and

5 a microprocessor configured to autonomously control the tool by generating the one or more control signals according to a power control sequence stored in a memory.

21. The apparatus as claimed in claim 20, wherein the microprocessor begins execution of the power control sequence in response to a trigger signal provided by 10 an external triggering device.

22. The apparatus as claimed in claim 21, wherein the external triggering device provides a battery voltage signal as the trigger signal.

15 23. The apparatus as claimed in claim 21, wherein the external triggering device provides a switch closure as the trigger signal.

24. The apparatus as claimed in claim 21, wherein the trigger signal powers the microprocessor.

20

25. The apparatus as claimed in claim 20, wherein the microprocessor is configured to monitor one or more sensors to generate the trigger signal internally.

26. The apparatus as claimed in any of claims 20 to 25, wherein the power 25 control sequence comprises applying the output voltage signal to the tool, removing the output voltage signal from the tool and again applying the output voltage signal to the tool.

27. The apparatus as claimed in any claims 20 to 26, wherein the power control 30 sequence is downloaded to the memory via a serial communications port.

28. The apparatus as claimed in claim 27, wherein the memory is a non-volatile memory.

29. A system comprising:

5 a non-electric cable;
 an electric downhole tool attached to the non-electric cable; and
 a power control interface comprising an output voltage circuit to generate an output voltage signal from a battery voltage and a microprocessor configured to autonomously control the tool by applying the output voltage signal to the tool and
10 varying the output voltage signal according to a power control sequence stored in a memory, wherein the power control sequence is initiated by a trigger signal.

30. The system as claimed in claim 29, wherein the tool is an inflatable tool.

15 31. The system as claimed in claim 30, wherein the inflatable tool comprises a first pump, a second pump and an inflatable member.

32. The system as claimed in claim 31, wherein the power control sequence comprises:

20 applying the output voltage signal to the inflatable tool to operate the first pump;
 removing the output voltage signal from the inflatable tool; and
 applying the output voltage signal to the inflatable tool to operate the second pump.

25

33. The system as claimed in claim 32, wherein the power control sequence further comprises reversing a polarity of the output voltage signal prior to applying the output voltage signal to the inflatable tool to operate the second pump.

30 34. The system as claimed in claim 33, wherein the power control sequence comprises monitoring a current draw of the inflatable tool while applying the output voltage signal to the inflatable tool to operate the first pump and removing the output

voltage signal from the inflatable tool in response to determining the current draw has exceeded a predetermined threshold value.

35. A method for operating an electric downhole tool comprising:
 - 5 attaching the tool to a power control interface;
 - lowering the tool and the power control interface down a wellbore on a non-electric cable;
 - receiving a trigger signal by the power control interface; and
 - in response to receiving the trigger signal, autonomously controlling the tool
- 10 with the power control interface by varying an output voltage supplied to the tool in accordance with a power control sequence.

36. The method as claimed in claim 35, further comprising downloading the power control sequence into memory of the power control interface.

15

37. The method as claimed in claim 35, wherein the power control sequence is chosen from a list of predetermined power control sequences.

38. The method as claimed in claim 37, further comprising downloading a selection parameter into memory of the power control interface, wherein the selection parameter determines which predetermined power control sequence is chosen from the list.

39. The method as claimed in claim 35, further comprising monitoring one or

25 more sensors by the power control interface.

40. The method as claimed in claim 39, wherein varying an output voltage supplied to the tool in accordance with the power control sequence comprises varying the output voltage as a function of data gathered from the one or more

30 sensors.

41. The method as claimed in claim 39, further comprising:
logging data gathered from the one or more sensors into memory; and
retrieving the logged sensor data from the memory.
- 5 42. A method for operating a plurality of electric downhole tools attached to a lowering member comprising:
generating an output voltage signal;
receiving a trigger signal by a microprocessor; and
selectively applying the output voltage signal to the plurality of tools according
10 to a power control sequence executed by the microprocessor.
43. The method as claimed in claim 42, wherein selectively applying the output voltage signal to the plurality of tools according to a power control sequence executed by the microprocessor comprises applying the output voltage signal to at
15 least two tools simultaneously.
44. The method as claimed in claim 42 or 43, further comprising downloading the power control sequence into a memory accessed by the microprocessor.
- 20 45. The method as claimed in claims 42 to 44, wherein the power control sequence is chosen from a list of predetermined power control sequences.
46. The method as claimed in claims 42 to 45, wherein at least one of the plurality of tools is an inflation tool.
- 25 47. The method as claimed in claims 42 to 46, wherein the lowering member is a nonconductive cable.

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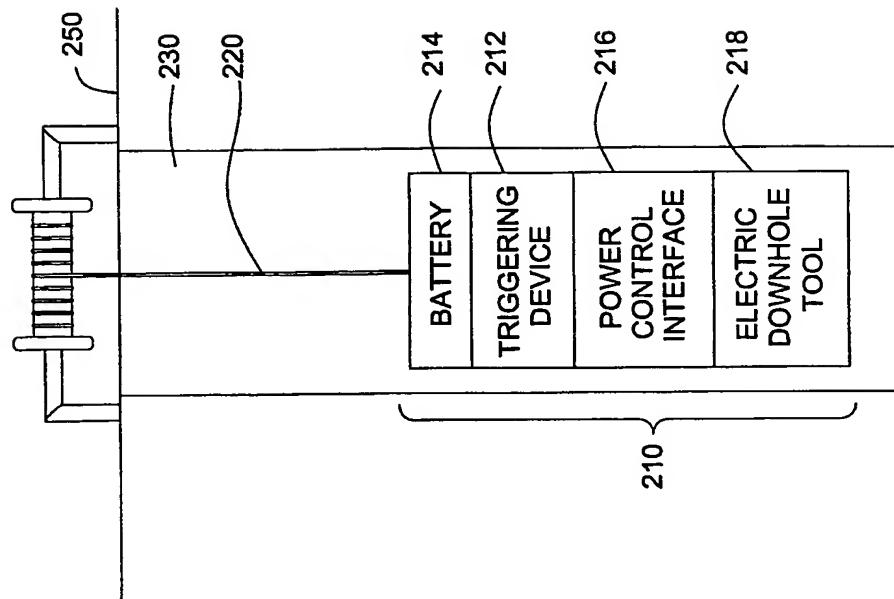
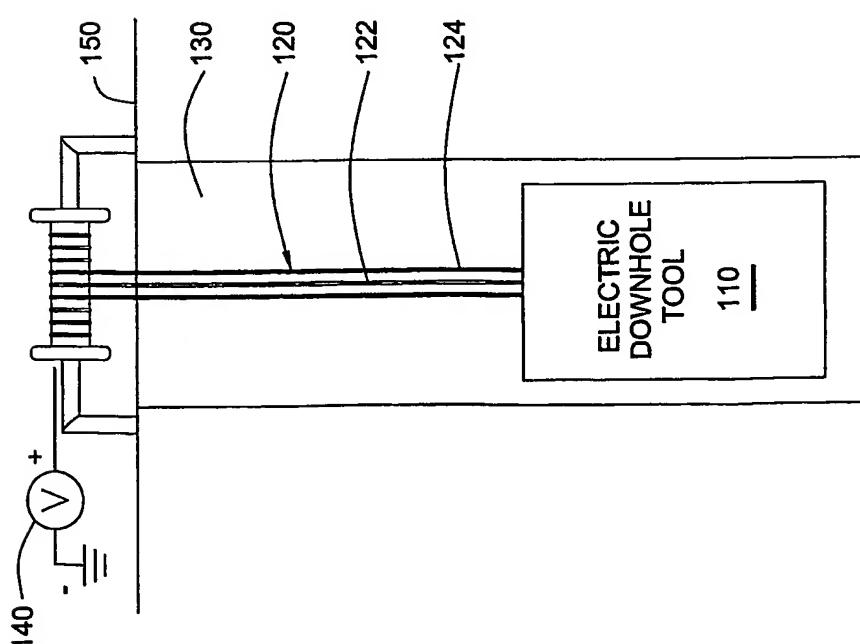


FIG. 2

FIG. 1
(PRIOR ART)

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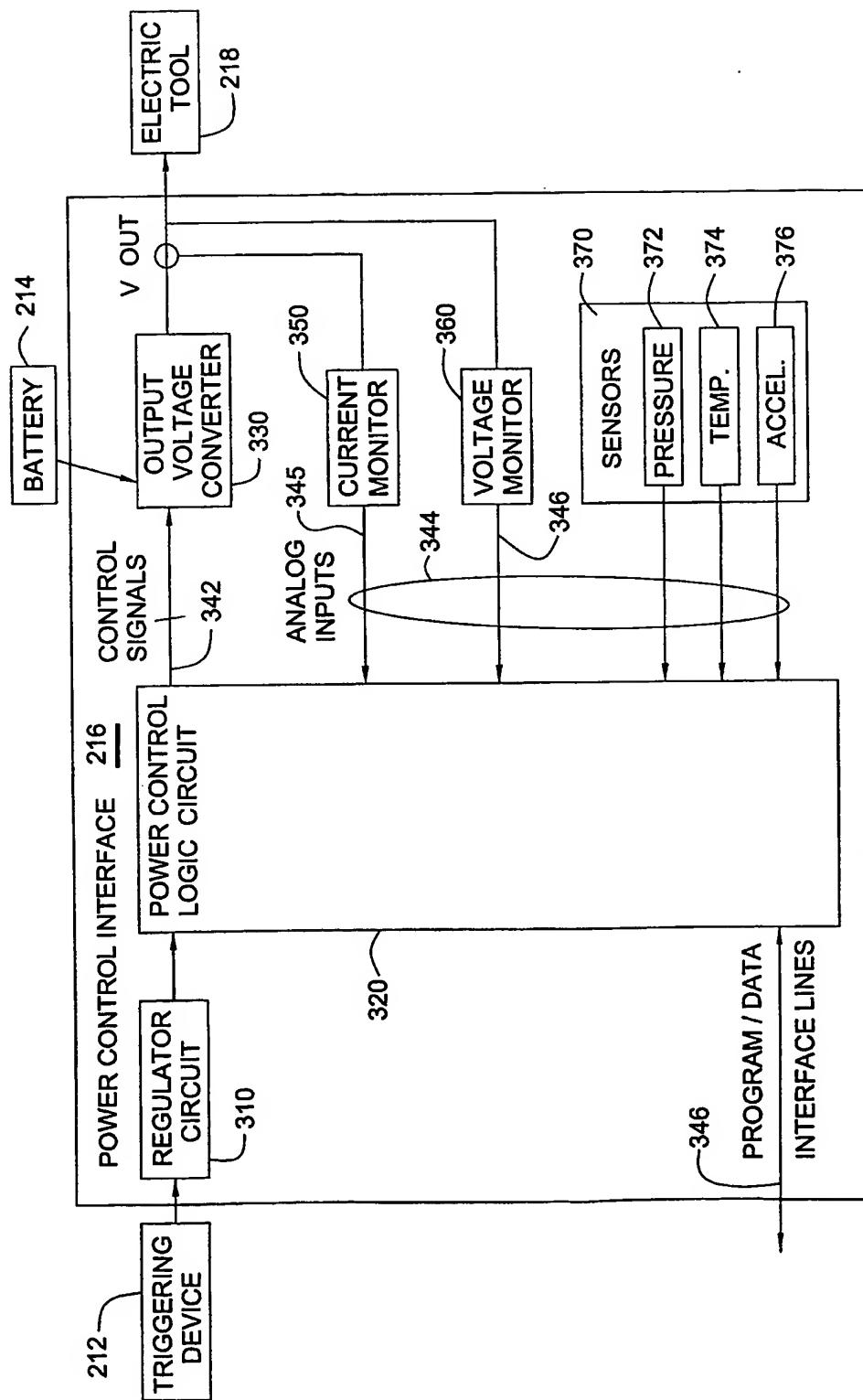


FIG. 3

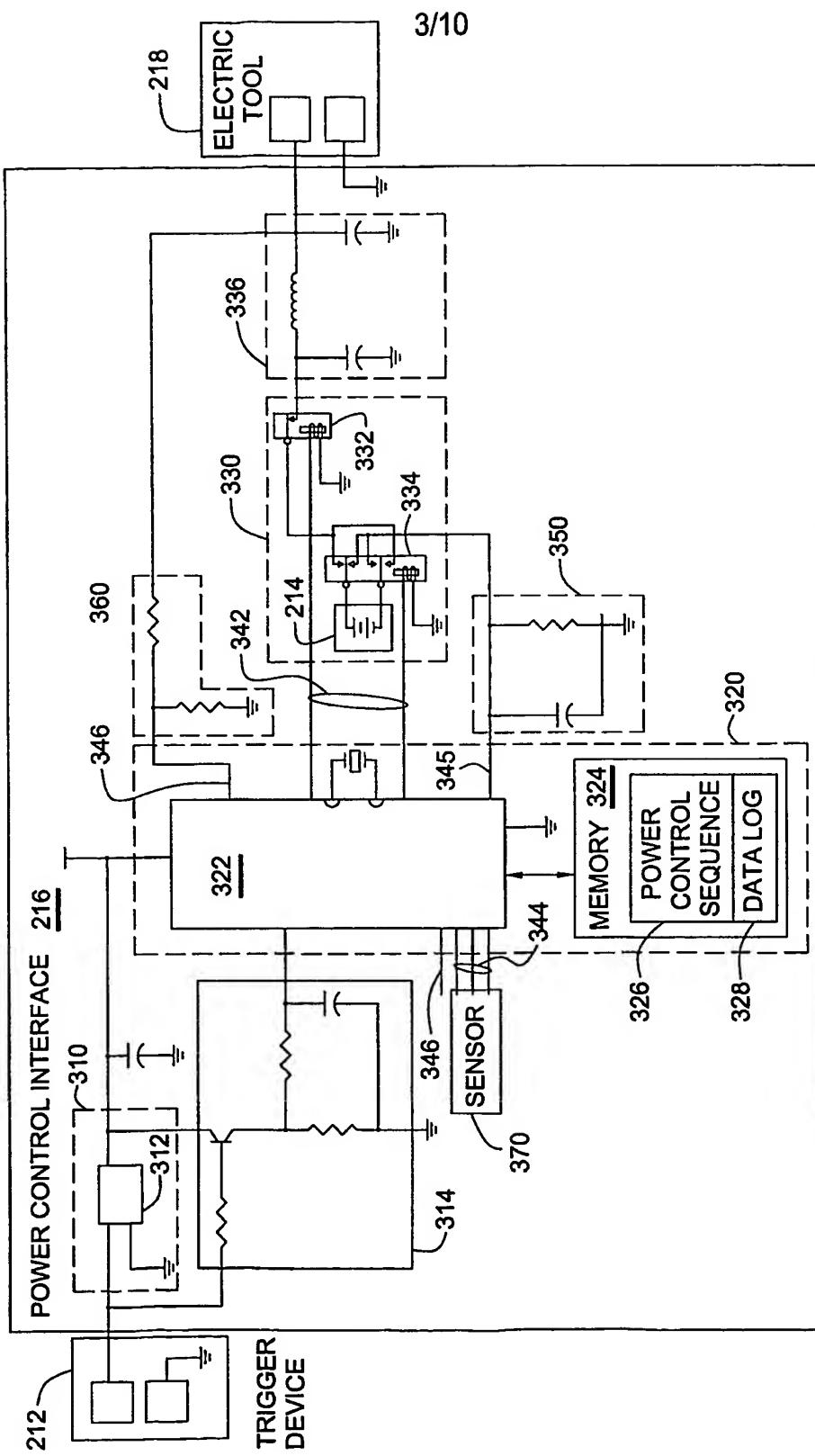


FIG. 4

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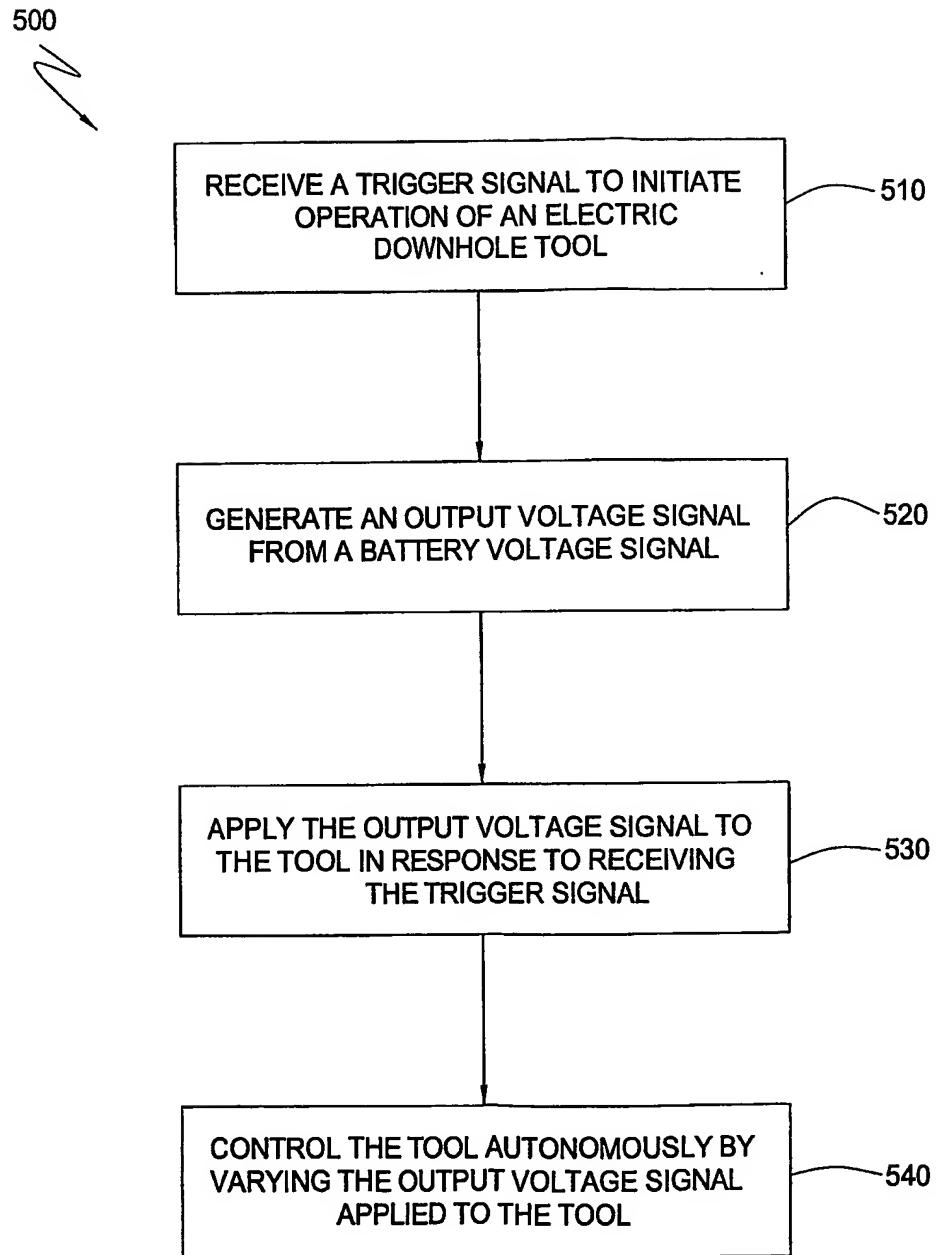


FIG. 5

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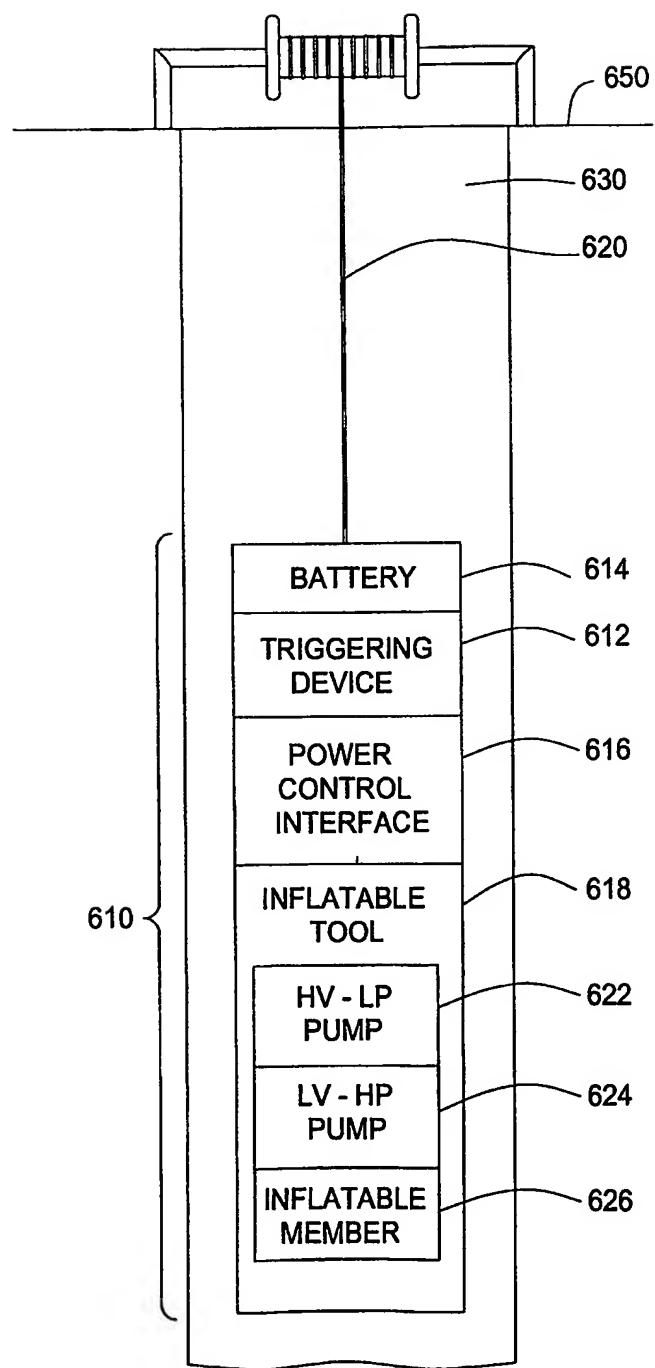


FIG. 6

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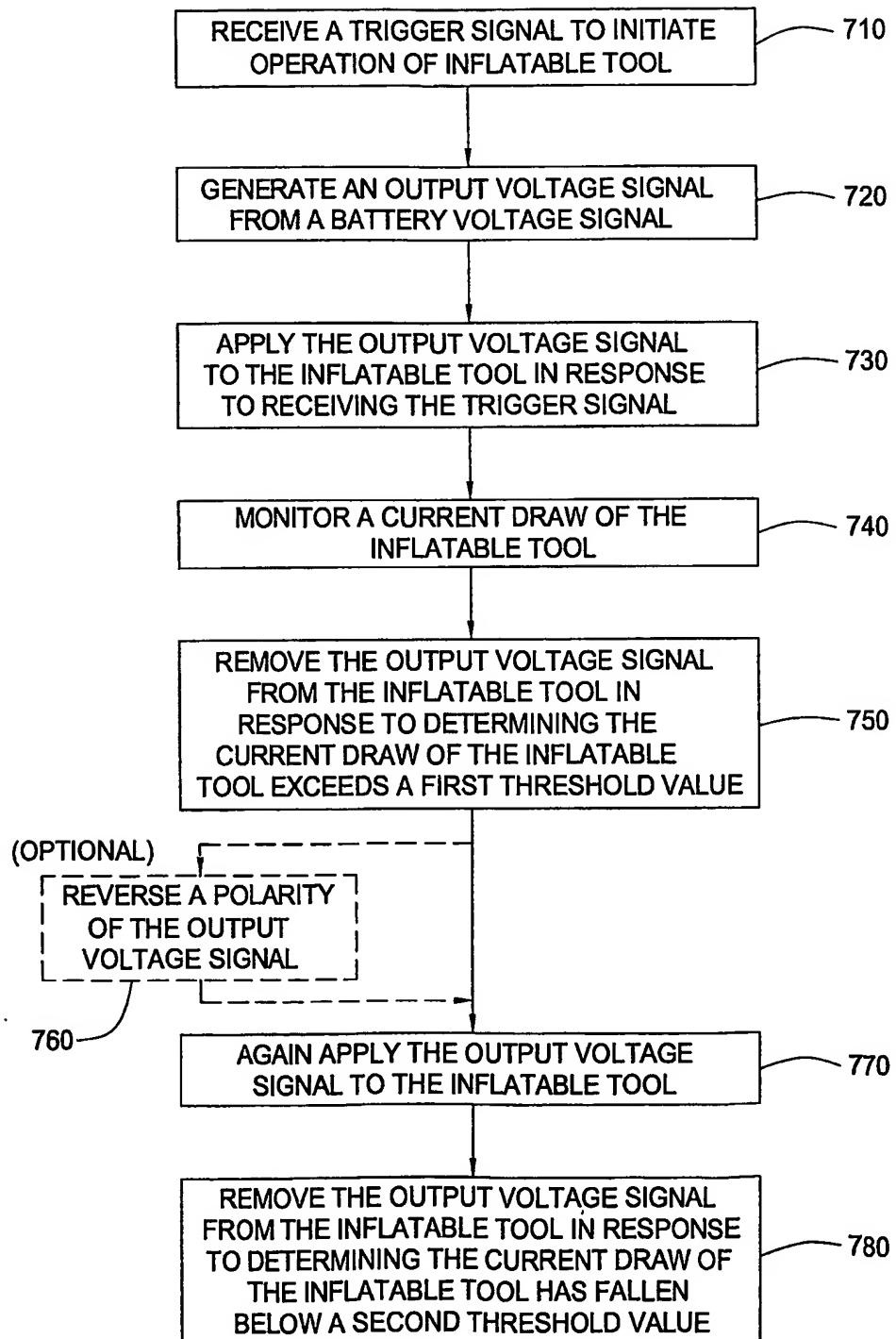


FIG. 7

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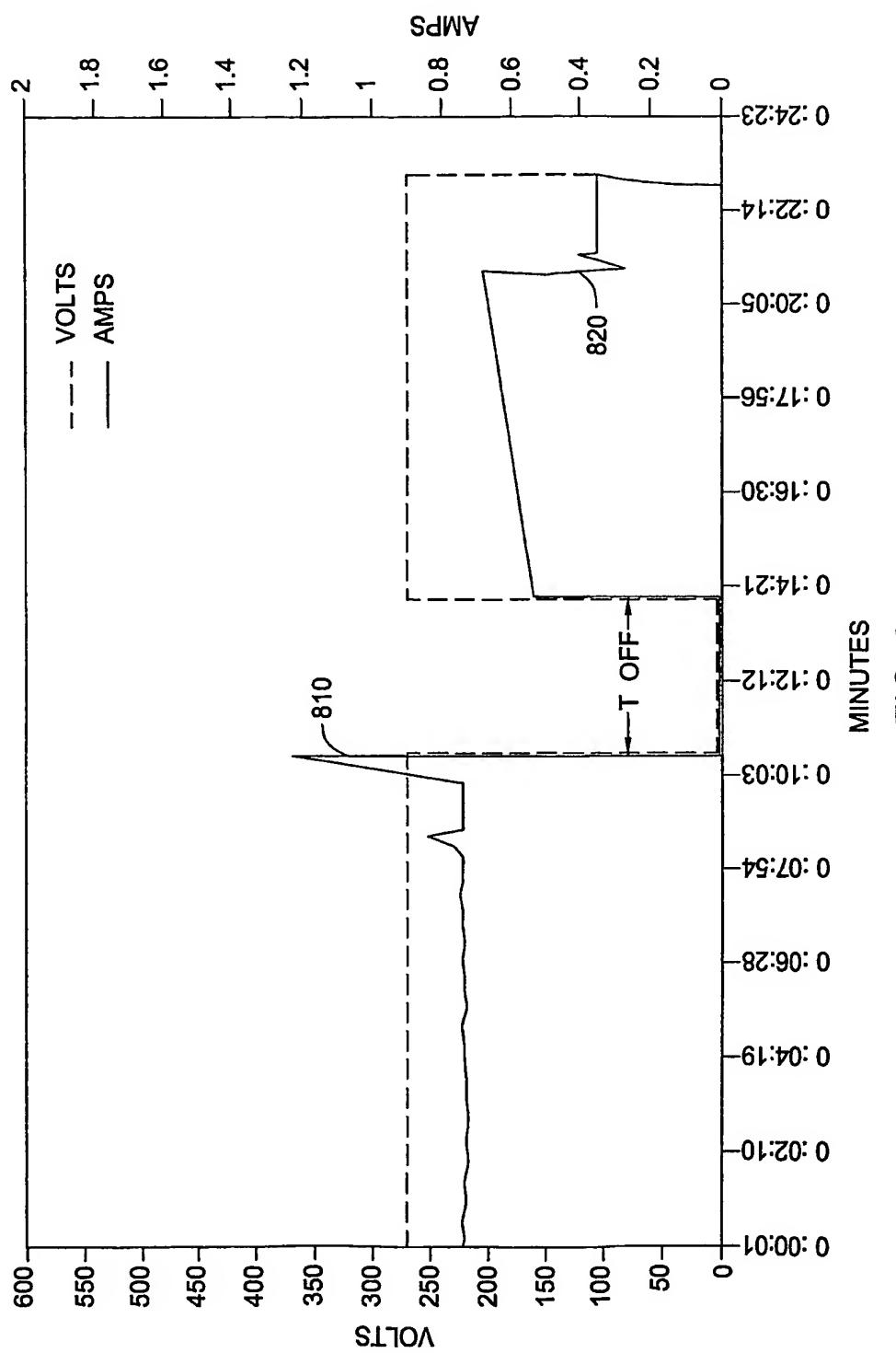


FIG. 8

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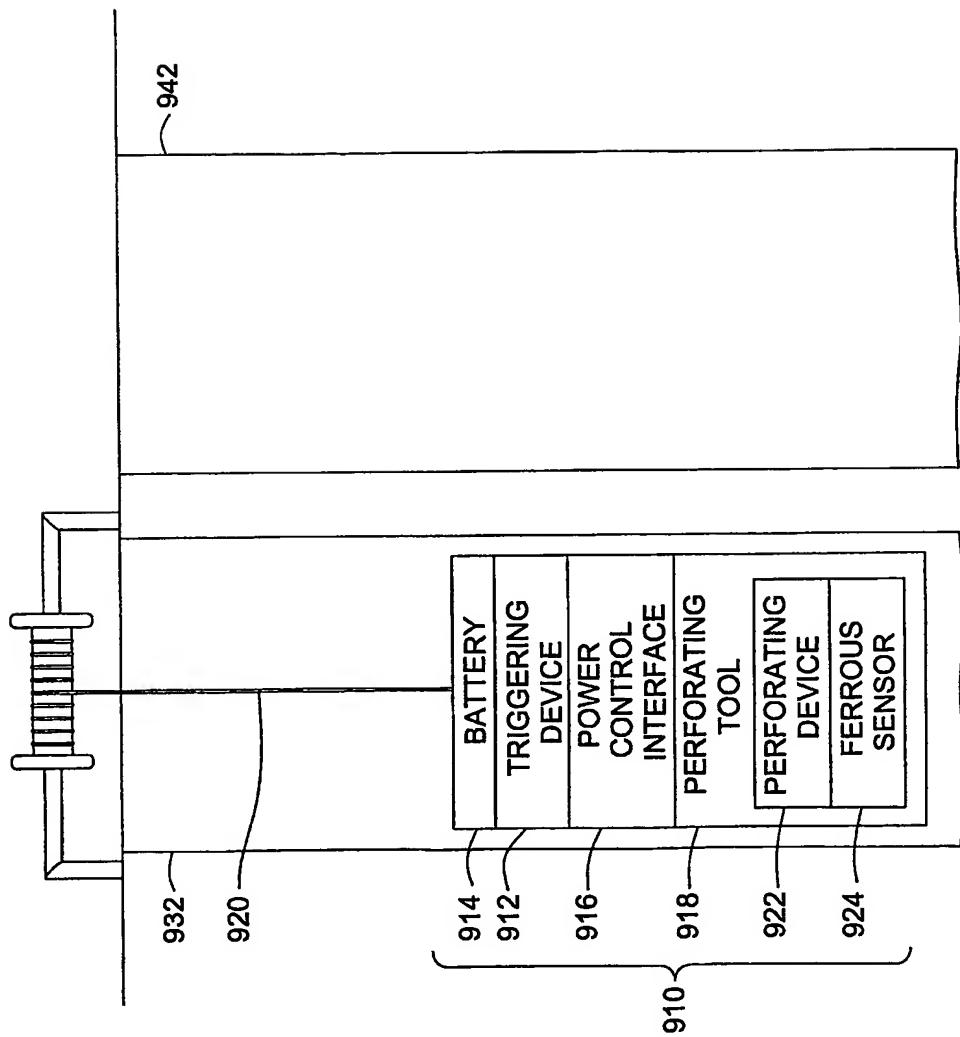


FIG. 9A

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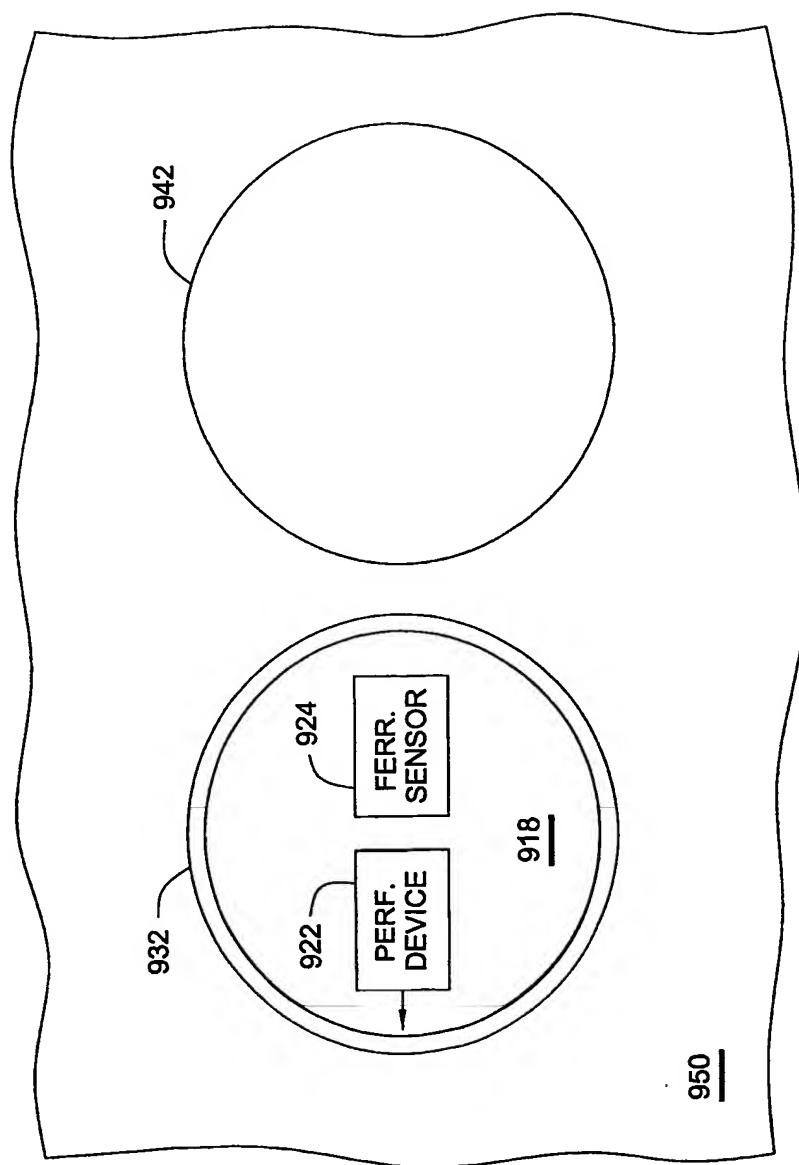


FIG. 9B

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1000



RECEIVE A TRIGGER SIGNAL TO INITIATE OPERATION
OF A PERFORATING TOOL

1010

GENERATE A SIGNAL TO ROTATE THE PERFORATING TOOL
WHILE MONITORING A SIGNAL GENERATED BY A SENSOR
INDICATING A LOCATION OF AN ADJACENT PIPE

1020

GENERATE A FIRING SIGNAL TO FIRE THE PERFORATING
TOOL IN RESPONSE TO DETERMINING A PERFORATING
DEVICE OF THE PERFORATING TOOL IS POINTING
AWAY FROM THE ADJACENT PIPE

1030

FIG. 10